Acidity in Lakes and Streams

Acid deposition can have serious effects on aquatic ecosystems. For example, aquatic organisms in acidified waters can develop calcium deficiencies that weaken bones and exoskeletons and cause eggs to be weak or brittle. Acidified waters can impair the ability of fish gills to extract oxygen from water and change the mobility of certain trace metals (e.g., aluminum, cadmium, manganese, iron, arsenic, mercury), which in turn can place fish and other species sensitive to these metals at risk (NAPAP, 1991). The Acid Deposition indicator explains the factors that contribute to acid deposition and describes how acid deposition patterns have changed over the last 25 years.

The susceptibility of a water body to acidification depends on the ability of the water and watershed soils to neutralize the acid deposition it receives. The best measure of this ability is acid neutralizing capacity (ANC), which characterizes the amount of dissolved compounds that will counteract acidity. Every body of water has a measurable ANC, which depends largely on the surrounding watershed's physical characteristics, such as geology, soils, and size. The ANC of a body of water reflects the relative proportions of positive and negative ions entering the water from sources such as atmospheric inputs and the soil and bedrock surrounding and underlying the water body. The higher the ANC, the more acid a water body can neutralize and the less susceptible it is to acidification. As ANC approaches zero, the ability to neutralize acidity decreases. Surface water with an ANC greater than 200 microequivalents per liter (μeq/L) is usually considered insensitive to acidification; surface water with an ANC less than 50 μeq/L is considered highly sensitive to acidification (is often seasonally acidic); and surface water with an ANC less than 0 μeq/L is considered chronically acidic, meaning the watershed no longer has the capacity to neutralize further acid deposition (U.S. EPA, 1988, 2003). ANC can be negative when anions exceed non-proton cations (i.e., when there are free protons [H^+ ions] in solution).

The National Acid Precipitation Assessment Program identified several regions in the U.S. as containing many of the surface waters sensitive to acidification (Exhibit 2). Where soil buffering capacity is poor, lakes and streams may be vulnerable to acidification (NAPAP, 1991).

This indicator is derived from ANC measurements on probability survey samples representing 8,664 lakes and 75,113 km of streams in the three geographic regions shown in Exhibit 2. These measurements were collected as part of the Temporally Integrated Monitoring of Ecosystems (TIME) project and on 74 additional acid-sensitive lakes and 75 acid-sensitive streams in the Long-Term Monitoring (LTM) project, for which data were available between 1991 and 2012 (U.S. EPA, 2014a). The lakes sampled include only those in areas potentially sensitive to acidification with areas greater than 1 hectare. This indicator focuses only on the northeastern U.S.; because monitoring is not ongoing for western, Midwestern, and southeastern water bodies, trend data for those parts of the country are not available.

What the Data Show

Between the early 1990s and 2012, ANC in lakes in the Adirondack Mountains and New England, and in streams in the Mid-Atlantic Appalachians (southern New York, west-central Pennsylvania, Virginia, and eastern West Virginia) increased to a degree where many water bodies that were considered "chronically acidic" in the early 1990s were no longer classified as such in 2012 (Exhibit 1). Specifically, between 1991-1994 and 2012, this analysis estimates that the percent of chronically acidic water bodies decreased in the Adirondack Mountains (from 15.0 percent to 6.9 percent) and in

New England (from 5.5 percent to 2.9 percent). Additionally, acid-sensitive streams in the Mid-Atlantic region of the Appalachian Mountains are also decreasing in acidity: the percent of chronically acidic streams in this region decreased from 4.3 percent in 1991-1994 to 3.5 percent in 2012. This trend suggests that surface waters in these three regions are beginning to recover from acidification, though acidic surface waters are still found in these regions.

The trend of increasing ANC in the Adirondack Mountains, New England, and the Mid-Atlantic Appalachian Mountains between the early 1990s and 2012 corresponds with a decrease in acid deposition in each of these regions (the Acid Deposition indicator) and reduced air emissions of the main precursors to acid deposition, which are sulfur dioxide (the Sulfur Dioxide Emissions indicator) and nitrogen oxides (the Nitrogen Oxides Emissions indicator).

Limitations

- ANC sampling is limited to three regions, all in the Northeast and Mid-Atlantic. (There is no long-term coverage in the Southeast, West, or Midwest.) These three regions were chosen for sampling because previous research has shown that they are among the most sensitive to acid deposition due to the soils and other watershed characteristics. In addition, as the Acid Deposition indicator shows, many of these regions receive the highest rates of acid deposition in the U.S. For these reasons, the waters sampled are likely to be at the greatest risk of becoming acidified.
- Interpreting trends for this indicator is complicated because multiple factors contribute to changes in ANC levels. For example, in areas where watershed soil characteristics are changing (e.g., decreases in concentrations of base cations in the soil), even dramatic reductions in acid deposition will not necessarily result in large rebounds in ANC levels.

Data Sources

Summary data in this indicator were provided by EPA’s Office of Atmospheric Programs and are taken from a publication documenting how surface waters have responded to reduced air emissions of acid rain precursors (U.S. EPA, 2003, 2014a) and from more recent unpublished results (U.S. EPA, 2014b). Trends are based on data collected in two networks: the TIME project and the LTM project, which are operated by numerous collaborators in state agencies, academic institutions, and other federal agencies. The trend data in this indicator are based on observations documented in several publications (U.S. EPA, 2003, 2014a).

References

NAPAP (National Acid Precipitation Assessment Program). 1991. Acid deposition: State of science and technology, volume II, aquatic processes and effects. Washington, DC.

U.S. EPA (United States Environmental Protection Agency). 2014a. Clean Air Interstate Rule, Acid Rain Program, and former NO_x budget trading program: 2012 Progress report, environmental and health results. https://www.epa.gov/sites/production/files/2015-08/documents/arpcair12_02.pdf (PDF) (23 pp, 8.34MB).

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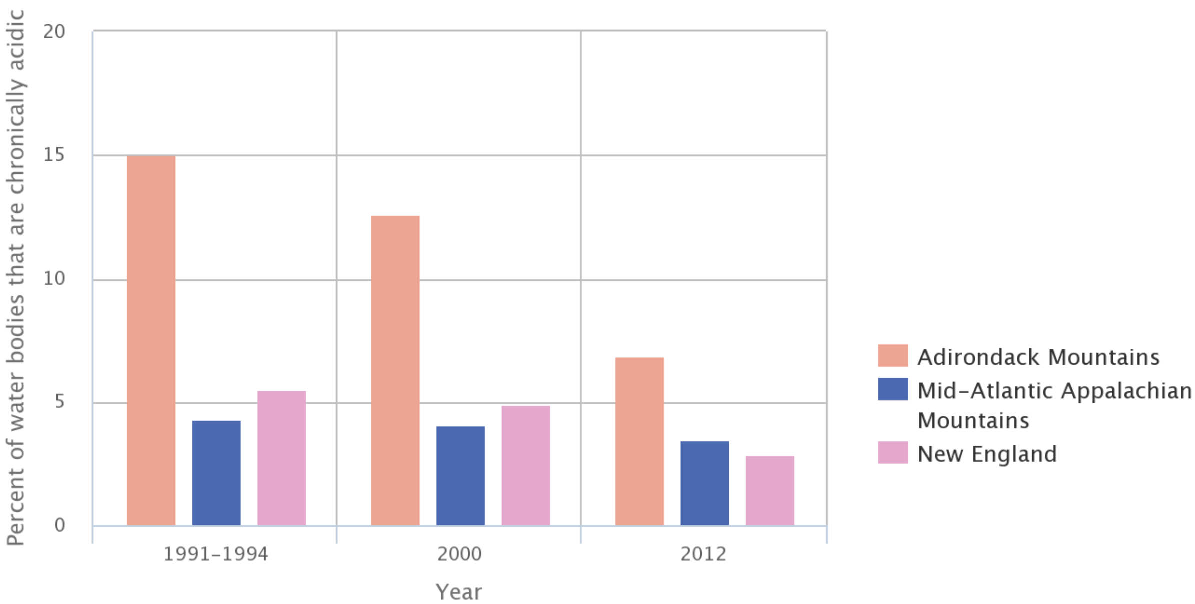
U.S. EPA. 2003. Stoddard, J.L., J.S. Kahl, F.A. Deviney, D.R. DeWalle, C.T. Driscoll, A.T. Herlihy, J.H. Kellogg, P.S. Murdoch, J.R. Webb, and K.E. Webster. Response of surface water chemistry to the Clean Air Act Amendments of 1990. EPA/620/R-03/001. Research Triangle Park, NC.

U.S. EPA. 1988. Chemical characteristics of streams in the mid-Atlantic and southeastern United States. Volume I: Population descriptions and physico-chemical relationships. EPA/600/3-88/021a. Washington, DC.

Exhibit 1. Lake and stream acidity in selected acid-sensitive regions in the U.S., 1991–2012



Coverage: 50 LTM and 43 TIME lakes in the Adirondack region, 26 LTM and 31 TIME lakes in the New England region, and 74 LTM and 56 TIME stream sites in the Mid-Atlantic Appalachian region.

Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2003, 2014a,b

Exhibit 2. Areas with acid-sensitive waters in the contiguous U.S.

Opacity: Click here to toggle legend

Acid-sensitive regions:

Adirondack Mountains New England Mid-Atlantic Appalachians

All areas with acid-sensitive waters

Trend analysis has not been conducted because these data represent a single snapshot in time. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: NAPAP, 1991